A KINEMATIC COMPARISON OF THE BLOCK JUMP AND A TRAINING JUMP AS PERFORMED BY ELITE COLLEGE AND RECREATIONAL FEMALE VOLLEYBALL PLAYERS

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While there are numerous vertical jumping investigations (Hudson, 1986, Bobbert, Huiling and Schenau, 1987) most study general vertical jumps in a basic laboratory setting. Static jumps, countermovement jumps with and without arm swing and plyometric jumps are often selected for analysis. Few have included the vertical jump as specifically used in performance. There may be distinct differences in jumps used in jump training and competition. The principle of specifity of training suggests that an athlete should train using drills and techniques that simulate competition situations and performance conditions.

Vertical jumping is a fundamental aspect of performance in a variety of athletic activities. Good jumping mechanics are important not only with respect to performance success but in preventing and minimizing both traumatic and overuse injuries. Jumper's knee is often result of forced lenghtening of active muscle which occurs on landing when the quadriceps muscle group eccentrically controls the slowing of the body against the force of gravity. Stacoff, Kaeli, & Stuessi (1987) report that impact forces in landing from jumps utilized in volleyball exceed the elastics limits of the cartilage in approximately 7% of the jumps analyzed. Colvin, Beal and Zier (1984) studied spike jumping of the 1984 U.S. Men's Olympic Volleyball team. It was suggested that optimal spike jumping technique is characterized by a forceful arm swing, a decisive blocking action with the arms and simultaneous extension of the hips, knee and ankles during the extension phase. Lesser skilled jumpers extend the knees and hips early during the set-up phase. Time of support ranged from .26s to .38s which emphasizes the speed of the loading period during the preparatory period. This influences muscle stretch velocity and transition between eccentric and concentric phases.

PURPOSE

The purpose of this study was to identify and measure selected components of the vertical jump as utilized in the specific skill of blocking a spike in volley-ball and countermovement jump with arm swing as utilized in jump training performed by elite and recreational female volleyball players.

METHODS

Six highly trained female volleyball players from the University of Illinois volleyball team (ELITE) and six recreational volleyball players (REC) participated in the study. The jumps analyzed in this study were the volleyball block jump (BJ) and a training jump (TJ) - performed by each subject and than three trials of each type jump were filmed with a LOCAM high speed camera operating at a film rate of 100 fps. Shuttered video cameras were used to film side and rear views. Block jumps were performed under a simulating competitive setting with each subject attempting to block spike hit by an attacker hitting a high set in middle front position.

Segmental end points were digitized with a Sonic Digitizer from adhesive markers placed on the right side of the subject to correspond with shoulder, elbow, wrist, hip, knee, ankle and 5th MTP. The raw data were smoothed with a second order low pass digital filter set at 6 Hz. The head, trunk, upper arm and thigh were measured as absolute angles from the vertical also computed as were angular positioning, ranges of motion, angular and linear velocities, height jumped, time of preparation, propulsion, flight and landing.

The propulsive phase was defined as the phase between the instant that the mass center passed its lowest position and the instant the feet lost contact with the floor. Height jumped was defined as the difference between the highest position reached by the body's CG and the position of CG in upright standing.

An analysis of variances was used to determine whether there were significant differences between the two groups of players and the two types of jumps. The significant level for statistical analysis was set at $p < 0.05$.

RESULTS AND DISCUSSION

The mean values (± s.d.) for the demographic data are age = 21 yrs (± 2.2), height = 175.2 cm (± 4.8) and body mass = 55.45kg (± 3.2). Table 1 presents for the groups of subjects values of general kinematic variables concerning TJ and BJ performances. Both groups jumped higher performing TJ than BJ, had greater vertical velocity of the cg at takeoff and a greater time of flight. On each of these variables the ELITE players performed significantly better than REC players. Of particular interest is the significant difference in landing times (TJ > BJ).

TABLE 1
Mean General Kinematic Variables

VARIABLE		RECREATIONAL TJ	RECREATIONAL BJ	ELITE TJ	ELITE BJ	SIGNIFICANCE ($p<0.05$)
Ht. of Jump (cm)	M	34.45	30.11	41.45	38.29	TJ > BJ
	SD	1.29	3.35	6.13	4.69	ELITE > REC
VEL-CG-TO (m/s)	M	2.56	2.14	2.73	2.72	TJ > BJ
	SD	.24	.19	.24	.25	ELITE > REC
Time-Prep (s)	M	.50	.33	.62	.32	
	SD	.14	.04	.10	.09	
Time-Leg PR (s)	M	.26	.22	.24	.23	
	SD	.02	.02	.04	.04	
Time-Flight (s)	M	.25	.24	.28	.27	TJ > BJ
	SD	.01	.02	.03	.02	ELITE > REC
Time-Land (s)	M	.15	.15	.17	.13	TJ > BJ
	SD	.01	.02	.03	.02	

Figure 1 illustrates how BJs and TJs were executed in this study by REC and ELITE players. The photo in the center captures the action of the blocker as she blocks the spike. The mean joint positions at ST-PR, TO, TD and EOL are detailed in Table 2. Differences in trunk and head positioning between TJs and BJs can be observed. Note the differences in landing positions between the TJs and BJs. Block jumping must be performed under the game condition restraints of jumping close to a net that cannot be touched and landing in a manner that keeps the athlete from crossing the center line. This necessitates that the blocker jump with the upper body in a vertical position. After placing the arms over the net to block the spike the ELITE group returns to the floor with a more hyperextended trunk than the REC group, perhaps a result of their ability to jump higher, "hang" longer (greater time of flight) and penetrate over the net with their arms to a greater degree.

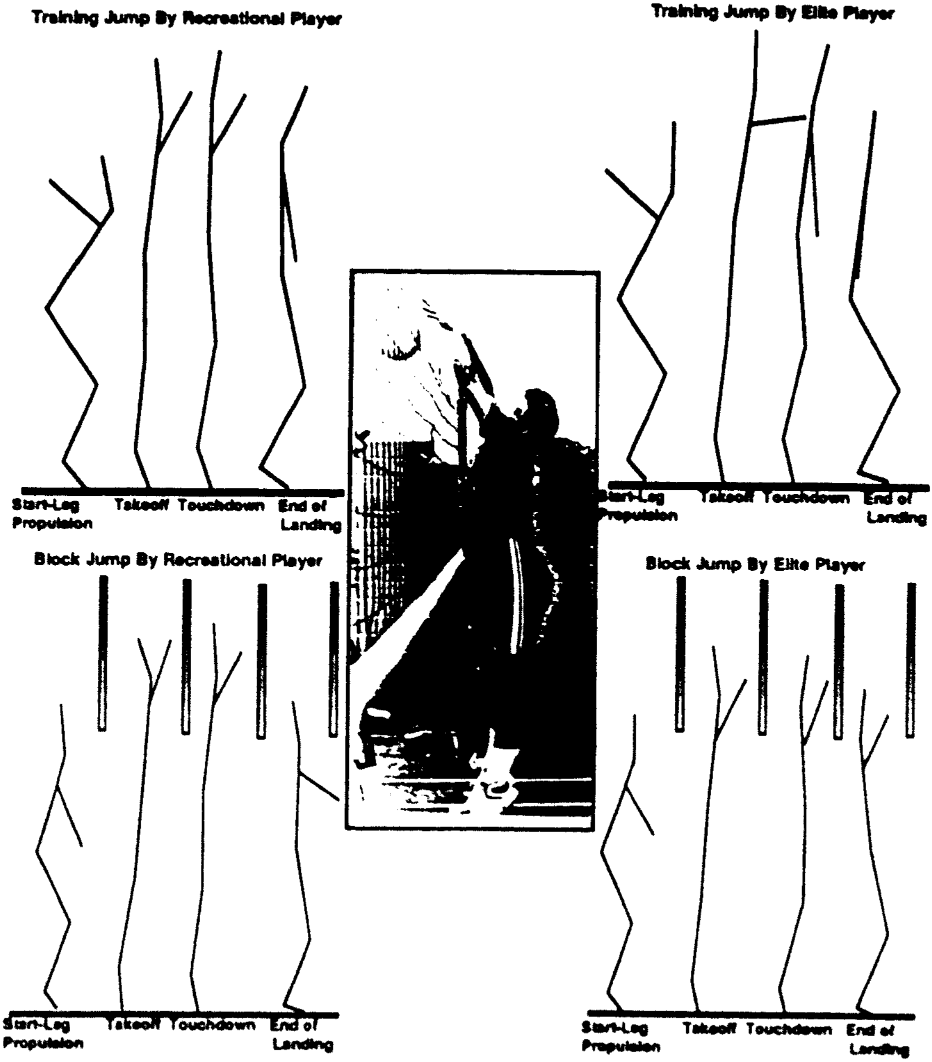

Figure 1: Jumping Techniques of Recreational and Elite Volleyball Players Performing Training Jumps and Block Jumps

TABLE 2

Mean Joint Angles (Deg) At Start of Propulsion (ST-PR) Takeoff (TO), Touchdown (TD), and End of Landing (EOL).

			RECREATIONAL				ELITE			
JOINT	JUMP		ST-PR	TO	TD	EOL	ST-PR	TO	TD	EOL
HEAD	TJ	M	-12.36	-2.28	9.06	5.70	4.77	4.77	13.94	10.55
		SD	14.99	12.85	14.04	11.22	12.46	12.46	10.50	13.19
	BJ	M	-12.53	-13.75	-17.95	-9.75	-3.58	1.25	3.42	3.13
		SD	13.37	12.56	15.81	14.30	17.83	6.42	11.04	5.51
TRUNK	TJ	M	41.65	9.04	2.05	1.00	43.55	12.95	5.82	12.83
		SD	1.35	6.03	10.04	8.23	11.58	7.30	6.34	12.92
	BJ	M	23.88	2.72	-1.65	-1.85	24.67	-3.76	-9.95	-8.79
		SD	9.90	12.92	8.30	8.60	11.33	4.49	3.52	4.72
HIP	TJ	M	45.45	-4.21	4.55	22.50	45.28	-5.34	8.77	34.63
		SD	3.45	8.86	3.96	4.31	6.64	5.24	7.02	5.81
	BJ	M	41.57	-6.70	8.92	22.26	42.44	-3.12	8.70	23.90
		SD	4.25	.87	5.60	2.71	8.95	4.19	4.98	3.61
KNEE	TJ	M	98.41	173.13	162.56	122.37	95.24	174.37	157.88	110.32
		SD	7.34	3.51	9.61	3.97	11.20	1.77	5.68	9.30
	BJ	M	106.97	173.95	172.03	129.66	106.18	177.11	158.49	122.31
		SD	14.12	4.30	6.08	9.83	11.93	2.38	7.10	5.37
ANKLE	TJ	M	83.18	150.57	139.43	83.72	86.34	153.54	140.96	80.59
		SD	7.86	10.23	9.57	5.91	6.24	7.09	5.05	5.74
	BJ	M	87.42	148.68	139.43	89.53	87.21	148.66	139.61	84.75
		SD	7.98	7.52	5.71	12.65	5.79	6.34	4.24	3.62

Table 3 shows mean joint ranges of motion during propulsion (leg thrust), average angular velocities at takeoff and peak velocities reached during the propulsion. The mean head and trunk ROMs and peak velocity of the head during propulsion was significantly higher in the TJs than in the BJs. Head and trunk movements are more restricted in the BJ because of the player's close proximity to the net. A significantly greater range of hip and knee extension occured during propulsion in TJ than in BJ, peak velocities differed significantly (593.93 deg/s - TJ and 512.23 deg/s - BJ). In the lower extremities (hip, knee, ankle) peak velocities were reached at takeoff or a few milliseconds prior to takeoff indicating simultaneous extension of these joints during propulsion.

TABLE 3

Mean Joint Ranges of Motion During Propulsion (ROM-PR-deg), Takeoff (TO), Average Velocity at Takeoff (AVG V-TO-deg/s), Peak Velocity During Propulsion (PEAK VEL-PK-deg/s).

			RECREATIONAL			ELITE			
JOINT	JUMP		ROM-PR (Deg)	AVG V-TO (Deg/s)	PEAK VEL-PR (Deg.s)	ROM-PR (Deg)	AVG V-TO (Deg/s)	PEAK VEL-PR (Deg/s)	SIGNIFICANCE (P<0.05)
HEAD	TJ	M	17.01	40.63	471.50	16.69	38.90	362.37	TJ > BJ -PEAK VEL
		SD	8.96	21.66	188.30	11.41	25.31	150.81	TJ > BJ-ROM
	BJ	M	9.43	43.80	245.54	7.02	31.64	184.00	
		SD	5.89	28.68	77.99	5.20	25.35	34.40	
TRUNK	TJ	M	38.72	92.67	281.01	48.88	117.66	248.69	TJ > BJ-ROM
		SD	10.12	24.84	76.71	11.28	21.09	25.46	
	BJ	M	27.94	124.87	264.62	28.63	121.40	238.20	
		SD	12.04	69.66	41.76	7.87	15.19	47.71	
HIP	TJ	M	54.11	209.48	559.17	50.62	211.41	688.30	TJ > BJ-PEAK VEL
		SD	5.03	28.92	59.77	8.16	22.83	122.83	TJ > BJ-ROM
	BJ	M	48.26	223.55	467.28	45.56	197.05	499.48	
		SD	4.62	25.33	28.13	6.56	24.74	73.65	
KNEE	TJ	M	74.72	290.65	947.42	79.13	330.44	1057.75	TJ > BJ-ROM
		SD	10.12	58.98	150.33	11.46	28.64	282.17	
	BJ	M	66.98	308.05	975.17	70.93	305.58	911.42	
		SD	18.29	73.04	154.44	13.70	48.31	144.08	
ANKLE	TJ	M	67.39	259.65	1097.00	67.20	285.42	1084.42	
		SD	8.72	30.59	226.33	10.07	58.07	362.36	
	BJ	M	61.26	284.52	860.83	61.45	251.53	906.08	
		SD	7.87	45.71	152.93	5.68	52.24	173.53	

Table 4 summarizes movements of the upper arm during the propulsion. In TJs the upper arm moves in sagittal plane from a position of hyperextension at the start of propulsion to a flexed position in front of the body at takeoff. In BJs the upper arm moves primarily in the frontal plane during the propulsion. The ELITE group did not use the upper arm in the same manner as the REC group during the BJs. The ELITE players start at the net with the arms extended overhead in front of the body and close to the net. As descent begins the arms do a quick "arm pump" action where they are rapidly brought in (adducted) close to the sides of the body, followed by vigorous abduction during propulsion and takeoff. The ELITE group had significantly higher mean upper arm velocities at takeoff (313.33 deg/s) during the BJ than the REC group (180.63 deg/s). In TJs peak velocities of the upper arm were reached before takeoff and deceleration was occuring at takeoff. This is in agreement with Colvin, Beal and Zier (1984) who suggest that the "blocking" with the arms enhances the transfer of monumentum created in the arms enhances the transfer of monumentum created in the arm swing to the body. In the BJs peak velocities were reached at or just prior to takeoff which suggest the use of the arms is quite different in generic (TJ) and performance jumps (BJ).

TABLE 4
Upper Arm Positioning at Start of Propulsion (ST-PR), Takeoff (TO), Average Angular Velocity During Propulsion (AVG VEL-PR), Peak Angular Velocity During Propulsion (PEAK VEL-PR) and Range of Motion During Propulsion (ROM-PR).

VARIABLE		SAGITTAL MOTION (FLEX/EXT) REC TJ	ELITE TJ	VARIABLE		FRONTAL MOTION (ABD/ADD) REC BJ	ELITE BJ
ST-PR (Deg)	M	-107.00	-118.33	START	M	49.17	76.83
	SD	8.00	19.05		SD	13.70	46.25
TO (Deg)	M	141.33	95.67	ST-PR (Deg)	M	73.17	63.50
	SD	24.04	55.32		SD	23.15	18.77
AVG VEL-PR (Deg/s)	M	607.57	516.17	TO (Deg)	M	146.50	151.33
	SD	71.13	121.69		SD	19.14	9.61
PEAK VEL-PR (Deg/s)	M	1173.52	1066.72	AVG VEL-PR (Deg/s)	M	180.63	313.33*
	SD	291.45	219.21		SD	24.08	98.56
ROM-PR (Deg)	M	254.50	214.00	ROM-PR (Deg)	M	97.33	96.83
	SD	34.20	56.32		SD	10.61	21.70

* ELITE AVG VEL-PR significantly higher ($p<0.05$) than REC.

Landing variables are shown in Table 5. Although ankle flexion during landing is comparable in the two types of jumps there is significantly less flexion in hips and knees in the BJs than in TJs. Under performance conditions landing may be complicated by the preceding events which occur in the blocking technique. After takeoff the blocker must move the hands above and over the net in an attempt to prevent the spiked ball from crossing the net. The skilled player, having a higher jump and longer time of flight, penetrates farther over the net than a lesser skilled player resulting in a piking action of the body between the trunk and thighs. A resulting action of this torque-counter-torque piking action is that the legs swing forward under the body. On descent the arms must be carefully retracted back across the net which leads to a "stiffer", straighter landing and also it may prevent forward motion of the body at impact which could possibly end in a net foul or center line violation.

TABLE 5
Mean Joint Ranges of Motion (Deg) During Landing

JUMP		RECREATIONAL HIP	RECREATIONAL KNEE	RECREATIONAL ANKLE	ELITE HIP	ELITE KNEE	ELITE ANKLE
TJ	M	17.35*	40.19**	55.88	26.19	47.56	55.47
	SD	2.74	7.78	8.16	10.50	13.92	6.32
BJ	M	13.33	40.58	56.09	15.20	33.01	54.86
	SD	7.04	2.54	9.61	4.40	3.10	3.09

*TJ HIP ROM significantly greater than BJ ($p<0.05$).
**TJ KNEE ROM significantly greater than BJ ($p<0.05$).

SUMMARY

Training jumps and performance jumps share certain common technique characteristics but there are also numerous and critical differences. The coach and athlete should exercise caution in using generic vertical jumps as the nucleus of a jump training program. In designing an effective jump training program emphasis should be placed on simulating performance requirements and rule restrictions imposed on the vertical jump under performance conditions.

1. Major differences between the selected TRAINING JUMP and BLOCK JUMP include:

   A. Use of arms in BJ is restricted. There is limited shoulder flexion in the BJ with exaggerated abduction moves employing different muscle groups than what would be used in the TJ which uses large ranges of shoulder extension/flexion and a minimum o abduction.
   B. Arms are decelerating at takeoff in TJs and are reaching maximum velocity at takeoff in BJs.
   C. Head and trunk positioning varies greatly between the TJ and BJ with more hyperextension used in the BJ.
   D. Greater landing forces may be occurring with the BJ as the player descends close to the net attempting to maintain balance. Shorter landing times and smaller ranges of motion in the lower extremities support this.

2. Differences between ELITE and REC players include:

   A. ELITE players use the arms differently in the BJ than do REC players. As the legs flex prior to extension the upper arms execute an arm pump by bringing the arms close to the body and then vigorous abduction occurs with takeoff.
   B. Several of the REC blockers took a hop or shuffle step forward before initiating the BJ.
   C. ELITE players through the mechanics and motor integration of their jumping technique reach a higher vertical velocity of their body mass cg at takeoff which results in a higher jump and a greater time of flight.
   D. A greater time of flight may allow the player more options as to blocking technique - i.e., skilled jumpers usually pike during the block and have better arm penetration over the net.

3. General conclusions and considerations include:

A. It is important for the jumper (especially in BJ) to land on both feet, thereby increasing the area over which force is absorbed.
B. To minimize landing forces keep the calf and thigh muscles strong which will help in force attenuation.
C. Proper shoewear can also help minimize landing forces.
D. Hips, knees, ankles perform forceful extension with maximum velocity reached just prior to or at time of take-off.
E. A good forceful vertical arm swing contributes to vertical ascent.
F. A downward prepatory countermovement with a quick transition to the propulsive phase is important in placing load on thigh muscles, stretching them prior to extension allowing for greater elastic recoil.

The ability to integrate and coordinate the complex task of vertical jumping is assumed to be task-specific. A major element in developing jumping techniques that will enhance the athlete's performance is to execute the motor task repeatedly in a correct manner. An athletes runs the risk of unlearning proper coordination in performance jumping if the jump training program is not carefully designed.

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